Employment Practices and Breast Cancer Among Radiologic Technologists

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A case-control study of breast cancer and employment practices among female radiologic technologists was conducted. The cohort from which cases and controls were derived included over 105,000 female medical radiation workers certified by the American Registry of Radiologic Technologists during 1926–1980. Breast cancer cases (n = 528) were individually matched to an average of five control subjects (n = 2628) based on year of birth, year of certification, and length of follow-up. Procedures most commonly performed by controls included fluoroscopy (93%), portable radiographs (92%), routine radiographs (92%), multifilm procedures (87%), dental x-rays (46%), radium therapy (31%), orthovoltage (23%), and cobalt-60 (21%). Breast cancer was not significantly increased with occupational experience with any of these procedures. Furthermore, risk was not related to number of years worked with a particular procedure. This study is reassuring in indicating that medical radiation workers are not at substantial risk for developing radiation-induced breast cancer. However, because only surrogate measures of radiation exposure were available, possibility of a small risk cannot be discounted. Ongoing follow-up of this cohort for incident cancers will incorporate detailed exposure assessment schemes, providing additional information on effects of long-term low-dose radiation through occupation.

Quantitative information useful for estimating the cancer risk associated with occupational exposure to radiation has been derived chiefly from populations exposed to brief, high doses, such as atomic bomb survivors.[1–3] Because radiation damage may be repaired when exposures are spread over many years, it is unclear whether extrapolations of these risk estimates are valid for exposures in occupational settings.[4,5]

Studies of radiation effects among occupationally exposed cohorts have focused primarily on male workers employed as radiologists,[6–9] US Army radiation technologists,[10] and nuclear energy and weapons industry workers.[11–13] Elevated mortality rates of several cancers, including leukemia, multiple myeloma, pancreas, lung, and skin, were observed.

Only two previous studies have provided data separately for women exposed to occupational radiation. A mortality study of 1285 female radium dial workers employed before 1930 initially suggested a significant positive association with breast cancer,[14] but upon further analysis, results were deemed inconsistent with a causal association with radium exposure.[15] A cohort study of medical diagnostic x-ray workers in China was the first study of medical radiation workers to include a large number of women (n = 5,443) and the only study to date to rely on incidence rather than mortality data.[16] Significant excesses of leukemia and esophagus, liver, and skin cancer were found for both genders combined. Nonsignificant elevations, based on small numbers of cases,

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were reported for cancers of the breast (20 women), thyroid (three men, five women), and bone (three men, one woman).

To study radiation carcinogenesis following repeated low-dose exposures over many years, the National Cancer Institute, in collaboration with the University of Minnesota, embarked upon an epidemiologic study of cancer risk among 143,517 radiologic technologists certified by the American Registry of Radiologic Technologists (ARRT). The study population is predominantly female (73%), and most were certified before age 25 (75%), affording the opportunity to study breast and other cancers among a large group of women first exposed to radiation at a relatively young age. This article presents the results of a case-control study of breast cancer associated with occupational exposure to radiation as measured by work practices and experiences with specific diagnostic and therapeutic radiation procedures.

Methods

The ARRT has been certifying medical radiation workers since 1926. Technologists are certified in three specialty areas: radiology, nuclear medicine, and radiation therapy. Methods for the cohort study and population characteristics have been described in detail.[17] Briefly, questionnaires were sent to all active and inactive registrants to obtain information on prevalent medical conditions, cancer risk factors, work histories, and personal x-ray exposures. Registrants lost to follow-up were traced using records from the Social Security Administration, the Health Care Financing Administration, state vital statistics offices, the National Death Index, and other sources. Reported leukemias and cancers of the breast, thyroid, and lung were confirmed using medical and hospital records.

Among the 105,385 female technologists, 3,539 women were deceased and 2,574 were lost to follow-up. Of the 99,272 who were contacted, 69,510 (70%) completed the 16-page questionnaire, and 9,506 (10%) responded to an abbreviated telephone interview about selected medical conditions. The remaining 20,256 (20%) did not respond, despite up to five attempts to contact them via mail and/or telephone.

Breast cancer cases and controls were selected from among the 69,510 women for whom breast cancer risk factor information was available from the questionnaire. There were 562 women in this group who reported a diagnosis of breast cancer; 15 had erroneous dates for breast cancer diagnosis, 12 had breast cancer before they were certified by ARRT, four were found not to have breast cancer based on histology, one did not match any control, one was reported by a surrogate respondent, and one was identified as a man. After excluding these 31 cases, 528 eligible cases remained. Up to five referent subjects who did not report breast cancer were matched to each case based on year of birth, year of certification, and length of follow-up.

Conditional logistic-regression methods were used to compare risk factor exposure among cases relative to their individually matched controls and to adjust for potential confounders.[18] This matched-set analysis allowed for a variable matching ratio of controls to cases. The relative risk for breast cancer was estimated by the odds ratio.

Associations with established breast cancer risk factors in this population were as expected.[19] Risk was associated with early menarche, nulliparity and late age at first birth, late age at menopause, family history of breast cancer, and personal history of breast biopsy. Risks associated with employment practices and work histories were adjusted for these factors. Approximate 95% confidence intervals (CIs) were computed using the Wald method.[20] Tests for trend were based on the likelihood ratio test.

Since this was a prevalence study of breast cancer, every effort was made to exclude from consideration any exposures that occurred after the index date, which was the date of diagnosis for the case, and comparable reference dates for her matched controls. The index date for controls was calculated by adding the length of time from ARRT certification to diagnosis for the case to the certification date for each of her matched controls. Thus, if a subject first worked with a particular procedure after the index date, she would not be considered to have worked with that procedure for purposes of these analyses. The number of years a technologist worked with a given procedure

TABLE 1
Employment Characteristics of Breast Cancer Cases and Controls, for Total Career and Prior to Index Date

	Cases (n = 528)		Controls (n = 2628)	
	Mean	Range	Mean	Range
Total career				
Number jobs held	3.6	0–8	3.5	0–8
Number years per job	6.1	0–47	5.9	0–55
% jobs dosimeter worn	52.7	0–100	53.7	0–100
Before index date*				
Number jobs held	3.4	0–8	3.3	0–8
Number years per job	5.4	0–40	5.3	0–55
Percent jobs dosimeter worn	51.9	0–100	53.3	0–100

* Index date = date of breast cancer diagnosis for cases and comparison date for controls, calculated by adding length of time from certification to diagnosis for case to certification dates for her matched controls.

was truncated at the index date to avoid counting exposures that could not have contributed to the cancer occurrence.

Results

Cases and controls were similar in terms of career employment, as well as employment before the index date, with respect to number of jobs held, average number of years at each job, and percentage of jobs with monitoring by dosimeters (Table 1). A large percentage of cases and controls (46% and 48%, respectively) continued to work after the index date. On average, cases worked for 22 years (18 years before breast cancer diagnosis) and controls worked for 21 years (17 years before the index date). Dosimeters were worn regularly by cases and controls during about half of the positions they held.

More than half of the cases (54%) and controls (53%) had one or more breaks in employment during their twenties and thirties (data not shown). The average age at start of break was 27 years for both groups. Average total length of the employment break truncated at the index date was the same for cases and controls (6 years); the average length of the longest break was also equivalent (5 years). Controls were somewhat more likely than cases to have had children (79% versus 73%) and slightly more likely to have given birth to their first child during the longest break in employment (48% versus 45%).

Distributions of cases and controls by selected work practices are presented in Table 2. Use of a lead apron or shielding when first working for all workers and for those who were currently working at the time of the survey were similar among cases and controls. The two groups were equally likely to have worn dosimeters, with no appreciable differences observed according to placement on the body.

Table 3 presents the risk of breast cancer associated with ever having worked with specific diagnostic and therapeutic procedures. Breast cancer was not increased following occupational experience with any of these procedures. Women who worked with portable radiographs, dental x-rays, and radium therapy were found to be at reduced risk of breast cancer; given that so many multiple comparisons were made, this finding is likely due to chance. Since technologists were likely to have worked with a variety of similar procedures, analyses were also conducted on broad groupings. Breast cancer was not associated with the use of any radiotherapy procedure (relative risk (RR) = 0.92; 95% CI = 0.8–1.1), any radioisotopes (RR = 0.99; 95% CI = 0.8–1.3), or any ultrasound or microwave diathermy (RR = 0.89; 95% CI = 0.7–1.2).

As shown in Table 4, there were no significant trends for number of years worked with any of the individual procedures examined. Negative associations with the use of dental x-rays and radium therapy were not supported by dose-response analyses of number of years worked with these procedures; however, a significant negative trend was found with the number of times portable x-rays were used (P trend = 0.03). Dose-response relationships were not found with number of years worked

TABLE 2
Work Practices Among Breast Cancer Cases and Controls

Work Practice	Cases (n = 528) No.	Cases %	Controls (n = 2628) No.	Controls %
All workers				
Lead apron or shield used when first working?				
Yes	445	84.3	2,248	85.5
No	73	13.8	286	10.9
Unknown	10	1.9	94	3.6
Dosimetry badge—usual placement?				
Never wore badge	78	14.8	387	14.7
Belt loop, waist, or side pocket	247	46.8	1,141	43.4
Breast pocket	73	13.8	327	12.4
Lapel	111	21.0	631	24.0
Other	9	1.7	42	1.6
Unknown	10	1.9	100	3.8
Hand or wrist dosimeter worn?				
Yes	17	3.2	95	3.6
No	491	93.0	2,345	89.2
Unknown	20	3.8	188	7.2
Current workers*				
Lead apron or shield used currently?				
Yes	167	87.4	895	91.9
No	14	7.3	53	5.4
Unknown	10	5.2	26	2.7
Dosimetry badge placement relative to apron?				
Badge not usually worn	6	3.1	44	4.5
Under the apron	64	33.5	316	32.4
Outside the apron	60	31.4	335	34.4
Varies, under or outside	35	18.3	169	17.4
Badge not worn, located in x-ray room	5	2.6	25	2.6
Unknown	21	11.0	85	8.7

* Percentages based on 191 cases and 974 controls working at time of survey.

TABLE 3
Risk of Breast Cancer Following Occupational Experience with Selected Diagnostic and Therapeutic Radiation Procedures

Worked with Procedure	Cases (*n* = 528)		Controls (*n* = 2628)		Relative Risk*	Adjusted Relative Risk†	95% Confidence Interval
	No.	%	No.	%			
Fluoroscopy	497	94.1	2453	93.3	1.16	1.14	(0.8–1.7)
Routine radiograph	486	91.9	2410	91.7	1.05	1.02	(0.7–1.5)
Portable radiograph	476	90.2	2428	92.4	0.54	0.54	(0.4–0.8)
Multifilm procedures	453	85.8	2276	86.6	0.93	0.85	(0.6–1.1)
Dental radiograph	218	41.3	1205	45.9	0.82	0.81	(0.7–1.0)
Radium therapy	140	26.5	820	31.2	0.80	0.77	(0.6–1.0)
Orthovoltage	130	24.6	594	22.6	1.12	1.04	(0.8–1.3)
Cobalt-60	103	19.5	540	20.5	0.93	0.89	(0.7–1.1)
Betatron	11	2.1	57	2.2	0.96	0.93	(0.5–1.8)
Other radiograph teletherapy	26	4.9	123	4.7	1.06	1.04	(0.7–1.6)
Other radioisotope therapy	46	8.7	265	10.1	0.85	0.82	(0.6–1.2)
Diagnostic radioisotopes	119	22.5	559	21.3	1.09	1.06	(0.8–1.3)
Microwave/ultrasound diathermy	54	10.2	262	10.0	1.03	1.02	(0.7–1.4)
Diagnostic ultrasonography	34	6.4	207	7.9	0.80	0.83	(0.6–1.2)
CAT scan	26	4.9	156	5.9	0.82	0.75	(0.5–1.2)

* Referent category comprised of individuals who never worked with procedure.
† Adjusted for age at menarche, age at first birth, age at menopause, family history of breast cancer, and personal history of breast biopsy.

with any radiotherapy (P trend = 0.72), any radioisotope (P trend = 0.58), or any ultrasound procedure (P trend = 0.89).

Discussion

Patterns of breast cancer consistent with ionizing radiation exposure have been reported in a variety of nonoccupationally exposed populations experiencing estimated average breast doses of 13–79 cGy. They include tuberculosis patients undergoing multiple chest fluoroscopies,[21,22] survivors of atomic bombs in Japan,[23] women treated for acute postpartum mastitis,[24] infants treated for enlarged thymus,[25] women receiving radiotherapy for ankylosing spondylitis,[26] and young girls who received multiple diagnostic x-rays for scoliosis.[27]

Our findings are not inconsistent with previous studies of breast cancer among radiation-exposed occupational cohorts. Breast cancer was not conclusively elevated following long-term, low-dose occupational exposures among women who worked as radium dial painters.[15] Among women x-ray workers in China, the patterns of breast cancer risk associated with length of employment and age and calendar year that employment began implicated occupational exposure to radiation as a causal agent.[16] However, the overall risk was only moderately elevated (RR = 1.5) and was not statistically significant.

Our data should be interpreted in light of certain strengths and weaknesses. This is the largest study to evaluate radiation effects among working women. Few studies have evaluated the combined effects of radiation and other breast cancer risk factors.[28] Risk factor information was available, making it possible to adjust risk estimates associated with employment experiences for these important determinants. It was interesting to note, however, that adjustment for established breast cancer risk factors made little difference in risk estimates for employment characteristics and work practices.

The study was limited by possible biases associated with studying long-term survivors of breast cancer. Nearly 400 women in the cohort died of breast cancer. If an association existed between radiation exposure and fatal breast cancer, a radiation hazard could have been missed. We are not aware of any studies in which radiation-induced breast cancers have been found to be more fatal than other breast cancers. Data from Japanese atomic bomb survivors do not support an association between survival and estimated probability that the breast cancer was caused by radiation (personal communication with Charles E. Land, PhD, March 1994). Additionally, breast cancer risk coefficients for A-bomb survivors did not differ substantially when based on cancer incidence versus mortality data.[29] Bias is unlikely because established breast cancer risk factors operated in a manner consistent with expectation; restricting the analyses to cases identified in 1980 or later yielded similar associations with known risk factors. A remaining limitation is the likelihood that some findings were due to chance as a result of the large number of multiple comparisons made.

Breast cancer cases and controls were similar with respect to employment characteristics and work practices as a radiologic technologist. They worked about the same number of years in the field, were equally likely to have continued working past the index date, and had comparable use of lead shielding and do-

TABLE 4
Risk of Breast Cancer Following Occupational Experience with Selected Diagnostic and Therapeutic Radiation Procedures, by Duration of Use

Procedure		No. of Years Used							P trend†
			<5*	5–9	10–14	15–19	20–24	25+	
Fluoroscopy	Adjusted RR‡		1.0	1.0	1.2	1.0	1.4	1.1	0.40
	95% CI		—	0.7–1.3	0.9–1.7	0.7–1.4	0.9–2.0	0.7–1.6	
	(cases, controls)§		(136, 742)	(114, 579)	(104, 426)	(51, 275)	(49, 184)	(46, 207)	
Routine radiograph	Adjusted RR‡		1.0	1.0	0.8	0.8	1.2	1.0	0.81
	95% CI		—	0.7–1.3	0.6–1.1	0.6–1.1	0.8–1.7	0.7–1.4	
	(cases, controls)		(116, 560)	(107, 502)	(80, 446)	(61, 339)	(61, 244)	(65, 284)	
Multifilm procedures	Adjusted RR‡		1.0	0.8	0.9	0.8	1.1	0.9	0.54
	95% CI		—	0.6–1.1	0.7–1.2	0.6–1.2	0.8–1.6	0.6–1.3	
	(cases , controls)		(168, 812)	(98, 525)	(77, 370)	(53, 288)	(48, 200)	(41, 211)	
		<1*	1–4	5–9	10–14	15+			
Dental radiograph	Adjusted RR‡	1.0	0.8	0.9	1.0	0.7			0.22
	95% CI	—	0.6–1.0	0.6–1.3	0.6–1.6	0.4–1.3			
	(cases, controls)	(337, 1570)	(79, 496)	(45, 221)	(24, 109)	(16, 96)			
Orthovoltage	Adjusted RR‡	1.0	0.9	1.0	1.4	1.3			0.29
	95% CI	—	0.6–1.3	0.6–1.6	0.8–2.5	0.7–2.2			
	(cases, controls)	(417, 2126)	(46, 243)	(22, 105)	(15, 51)	(16, 61)			
Radium therapy	Adjusted RR‡	1.0	0.6	1.1					0.73
	95% CI	—	0.4–0.8	0.7–1.5					
	(cases, controls)	(419, 1964)	(50, 373)	(45, 197)					
Cobalt-60	Adjusted RR‡	1.0	0.8	0.9					0.52
	95% CI	—	0.5–1.2	0.6–1.6					
	(cases, controls)	(463, 2266)	(37, 221)	(19, 96)					
Other radio isotope therapy	Adjusted RR‡	1.0	0.8	0.7					0.43
	95% CI	—	0.4–1.3	0.4–1.4					
	(cases, controls)	(490, 2408)	(15, 100)	(11, 67)					
Other radio-graph tele-therapy	Adjusted RR‡	1.0	0.9	1.5					0.31
	95% CI	—	0.4–2.0	0.7–3.1					
	(cases, controls)	(505, 2528)	(8, 45)	(11, 31)					
Diagnostic radioiso-topes	Adjusted RR‡	1.0	1.2	1.1					0.27
	95% CI	—	0.9–1.7	0.7–1.7					
	(cases, controls)	(433, 2220)	(54, 227)	(27, 121)					
Microwave/ ultrasound diathermy	Adjusted RR‡	1.0	0.7	1.3					0.79
	95% CI	—	0.4–1.2	0.8–2.2					
	(cases, controls)	(481, 2389)	(17, 118)	(20, 75)					
		<1*	1+						
Betatron	Adjusted RR‡	1.0	1.1						0.38
	95% CI	—	0.4–2.7						
	(cases, controls)	(522, 2594)	(6, 26)						
CAT scan	Adjusted RR‡	1.0	0.7						0.48
	95% CI	—	0.4–1.5						
	(cases, controls)	(510, 2500)	(10, 61)						
Diagnostic ultra-sound	Adjusted RR‡	1.0	0.6						0.14
	95% CI	—	0.3–1.2						
	(cases, controls)	(505, 2462)	(11, 87)						

* Referent category.
† Trend tests based on continuous value of years worked with a particular procedure.
‡ Relative risk adjusted for age at menarche, age at first birth, age at menopause, family history of breast cancer, and personal history of breast biopsy.
§ Number of exposed cases and controls.

simeters. Overall work experience with a variety of radiographic procedures was not associated with an increased risk of breast cancer, and no dose response was apparent for number of years worked with any procedure. The finding of a significant negative trend in risk of breast cancer with number of times using a portable x-ray machine was unexpected and may be due to chance, given the large number of comparisons made.

Conclusion

Data from this study are encouraging because they indicate that prevailing occupational exposures in the medical radiation setting do not place a woman at unusually high risk of developing breast cancer.[30] There were no detectable associations of breast cancer with occupational use of any diagnostic or therapeutic procedure or group of procedures. Additionally, duration of use of these procedures was not related to breast cancer. Possible explanations for an absence of association with intermittent long-term exposures include extremely low doses, imprecise measures of exposure, relatively short follow-up, and lower risk than expected due to the fractionated nature of the exposure.

Future efforts will focus on the use of biological markers of dosimetry to more accurately assign individuals to dose categories. Early results from a pilot study utilizing glycophorin-A and fluorescent in situ hybridization techniques revealed detectable increases in the number of somatic cell mutations among individuals with documented exposures over 35 cGy. These methods will be especially useful for characterizing exposure levels among early ARRT registrants. These women are likely to shed the most light on the risk of breast cancer following radiation exposures in the occupational setting, because of their long follow-up experience and likelihood of higher radiation exposures.

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